WIRELESS POWER SYSTEM WITH AMBIENT FIELD NULLING

[0001] This application is a division of U.S. patent application Ser. No. 15/980,401 filed May 15, 2018, which claims the benefit of provisional patent application No. 62/609,112, filed on Dec. 21, 2017, each of which is hereby incorporated by reference herein in its entirety.

FIELD

[0002] This relates generally to power systems, and, more particularly, to wireless power systems for charging electronic devices.

BACKGROUND

[0003] In a wireless charging system, a wireless charging mat wirelessly transmits power to a portable electronic device that is placed on the mat. The portable electronic device has a receiving coil and rectifier circuitry for receiving wireless alternating-current (AC) power from a coil in the wireless charging mat that is overlapped by the receiving coil. The rectifier converts received AC power into direct-current (DC) power.

SUMMARY

[0004] A wireless power system uses a wireless power transmitting device to transmit wireless power to wireless power receiving devices. The wireless power transmitting device has wireless power transmitting coils that extend under a wireless charging surface.

[0005] In some configurations, non-power-transmitting coils (ambient magnetic field reduction coils) and magnetic sensors may be included in the wireless power transmitting device. Adjustments to the wireless power transmitting coils and optional adjustments to the non-power-transmitting coils are used to produce nulling magnetic fields during wireless power transmission operations. Magnetic sensors gather optional magnetic field measurements for feedback.

[0006] During wireless power transfer operations, control circuitry in the wireless power transmitting device adjusts drive signal phase and/or magnitude as drive signals are applied to the wireless power transmitting coils and non-power-transmitting coils to reduce ambient magnetic fields. The drive signal adjustments are made based on device type information and other information received from the wireless power receiving devices and/or magnetic sensor readings from the magnetic sensors. In-phase or out-of-phase drive signals are applied to minimize ambient fields depending on device type.

[0007] Multiple wireless power receiving devices may be present on the charging surface. In this type of situation, the wireless power transmitting device transmits wireless power using sets of coils that are coupled to respective wireless power receiving devices while making adjustments to drive signal phase and magnitude for each coil to reduce ambient field emission.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic diagram of an illustrative wireless charging system that includes a wireless power transmitting device and a wireless power receiving device in accordance with an embodiment.

[0009] FIG. **2** is a circuit diagram of illustrative wireless power transmitting circuitry and illustrative wireless power receiving circuitry in accordance with an embodiment.

[0010] FIG. **3** is a top view of an illustrative wireless power transmitting device on which a wireless power receiving device has been placed in accordance with an embodiment.

[0011] FIG. **4** is a top view of an illustrative wireless power transmitting coil in accordance with an embodiment.

[0012] FIG. **5** is a top view of an illustrative wireless power transmitting device with an array of coils in multiple layers in accordance with an embodiment.

[0013] FIG. **6** is a side view of an illustrative coil in accordance with an embodiment.

[0014] FIG. **7** is a perspective view of an illustrative wireless power transmitting coil in accordance with an embodiment.

[0015] FIG. **8** is a top view of an illustrative wireless power receiving coil in a wireless power receiving device and associated coils in a wireless power transmitting device in accordance with an embodiment.

[0016] FIG. **9** is a side view of an illustrative wireless power receiving coil in another wireless power receiving device and associated coils in a wireless power transmitting device in accordance with an embodiment.

[0017] FIG. **10** is a perspective view of an illustrative set of wireless power receiving devices on a wireless power transmitting device in accordance with an embodiment.

[0018] FIG. **11** is a graph of illustrative signals that may be used to drive coils in a wireless power transmitting device in accordance with an embodiment.

[0019] FIG. **12** is a cross-sectional side view of an illustrative wireless power transmitting coil and an associated supplemental non-wireless-power-transmitting coil for nulling ambient fields in accordance with an embodiment.

[0020] FIG. **13** is a top view of an illustrative wireless power transmitting device with supplemental coils and magnetic sensors in accordance with an embodiment.

[0021] FIG. **14** is a flow chart of illustrative operations involved in operating a wireless power system in accordance with an embodiment.

DETAILED DESCRIPTION

[0022] A wireless power system has a wireless power transmitting device such as a wireless charging mat. The wireless power transmitting device wirelessly transmits power to a wireless power receiving device such as a wristwatch, cellular telephone, tablet computer, laptop computer, wireless headphone (earbuds) charging case, or other electronic device. The wireless power receiving device uses power from the wireless power transmitting device for powering the device and for charging an internal battery.

[0023] The wireless power transmitting device has an array of wireless power transmitting coils arranged in multiple layers under a charging surface. During operation, the wireless power transmitting coils are used to transmit wireless power signals that are received by a wireless power receiving coil in the wireless power receiving device. Each wireless power transmitting coil may be connected to a respective capacitor in a resonant circuit. Optional magnetic sensors and supplemental field-nulling coils may be included in the wireless power transmitting device. During operation, the signals to the coils in the transmitting device